

The National Nanotechnology Initiative and Nanoscience User Facilities in the United States

Dr. Altaf H. Carim

Co-chair
Nanoscale Science, Engineering, and Technology (NSET) Subcommittee
National Science and Technology Council

Scientific User Facilities Division
Office of Basic Energy Sciences
Office of Science
U.S. Department of Energy

The Second Tri-National Workshop on Standards for Nanotechnology

NIST, Gaithersburg, MD

February 6, 2008

*What is the National Nanotechnology Initiative?

- The NNI is an interagency program that coordinates Federal nanoscale research and development activities and related efforts among various participating entities (currently 25)
- The NNI began in 2001 and its activities were codified and further defined in the 21st Century Nanotechnology Research and Development Act (Dec. 2003)
- Planned federal NNI expenditures
 are over \$1.4 billion in FY 2008

PUBLIC LAW 108-153-DEC. 3, 2003

117 STAT, 1923

Public Law 108-153

An Act

To authorize appropriations for nanoscience, nanoengineering, and nanotechnology research, and for other purposes.

es of 21st Century Nanotechnology Bessearch and Development A

This Act may be cited as the "21st Century Nanotechnolog Research and Development Act".

15

SEC. 2. NATIONAL NANOTECHNOLOGY PROGRAM.—The Preside (a) NATIONAL NANOTECHNOLOGY PROGRAM.—The Preside shall implement a National Nanotechnology Program. Throu appropriate agencies, councils, and the National Nanotechnolo Coordination Office established in section 3, the Program shall

(1) establish the goals, priorities, and metrics for evaluation for Federal nanotechnology research, development, and other activities; (2) invest in Federal research and development programs

in nanotechnology and related sciences to achieve those gos and

nanotechnology research, development, and other activities undertaken pursuant to the Program.

(b) PROGRAM ACTIVITIES.—The activities of the Program shall include—

(1) developing a fundamental understanding of matter that enables control and manipulation at the nanoscale; (2) providing grants to individual investigators and interdisciplinary teams of investigators; (3) establishing a network of advanced technology user

(4) establishing, on a merit-reviewed and competitive basis interdisciplinary, nanotechnology research, conters, which

(A) interact and collaborate to foster the exchange technical information and best practices;
(B) involve academic institutions or national laborations.

tories and other partners, which may include States an industry; (C) make use of existing expertise in nanotechnolog

in their regions and nationally;

(D) make use of ongoing research and developme at the micrometer scale to support their work





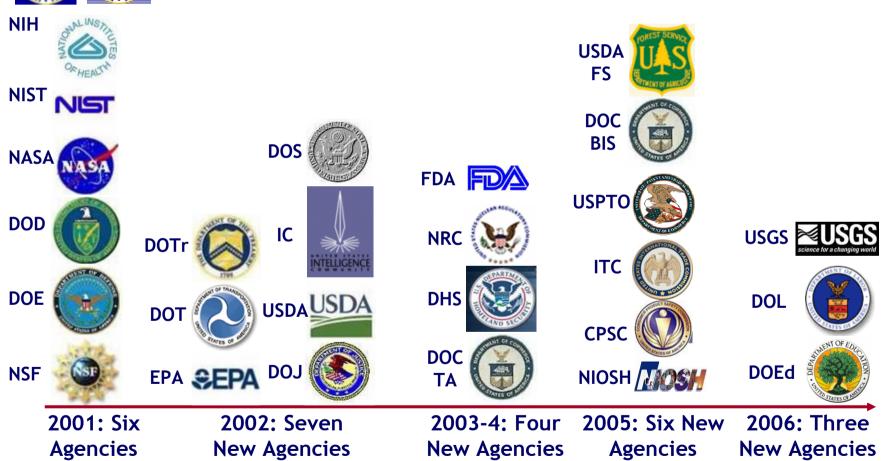
Participating Agencies in the NNI







- Six agencies developed original 2001 NNI proposal
- Now have 25 NSET Subcommittee member agencies





The NNI definition of "nanotechnology"

What is "nanotechnology"?

- Nanotechnology is the understanding and control of matter at dimensions between approximately 1 and 100 nanometers, where unique phenomena enable novel application.
- Nanotechnology involves imaging, measuring, modeling, and manipulating matter at this length scale
- With reference to the NNI, the term is meant to broadly encompass nanoscale science, engineering, and technology
- Not just another step towards miniaturization; fundamental differences in physical, chemical, and biological behavior at this level compared to bulk materials or individual atoms/molecules
 - quantum phenomena
 - dominance of surfaces
 - self-assembly

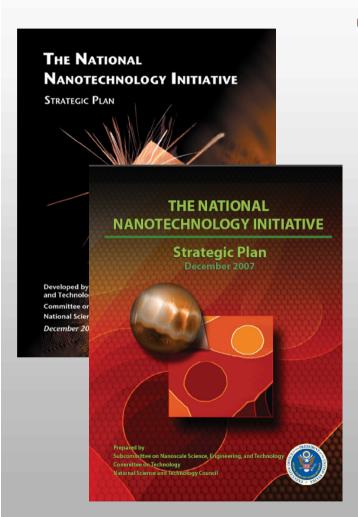


NNI activities and documents inform agencies, report outcomes, and serve as resources





Standards development in the NNI Strategic Plan

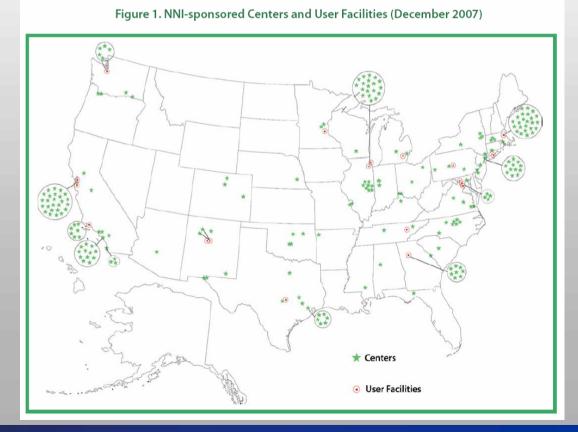


Both the original (December 2004) and recently revised (December 2007) NNI Strategic Plans explicitly acknowledge the importance of standards. One of the eight NNI Program Component Areas is "Instrumentation Research, Metrology, and Standards for Nanotechnology," and the interagency coordinating group has explicitly supported ANSI, OECD, and other activities in this area.



User Facilities for Nanoscience

- NNI user facilities provide critical scientific infrastructure. They make advanced experimental and theoretical capabilities accessible to researchers from academia, industry, and government laboratories; a vital component of this infrastructure are the scientific and technical staff members at these facilities.
- User facilities are supported by various U.S. Federal agencies:
 - National Institute of Standards and Technology
 - National Institutes of Health
 - National Science Foundation
 - Department of Energy





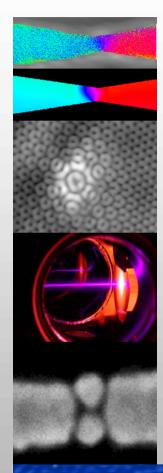
CNST – NIST's Center for Nanoscale Science and Technology



photo courtesy HDR Architecture, Inc./Steve Hall © Hedrich Blessii

- Provides measurement methods, standards and technology to support all phases of nanotechnology development from discovery to production,
- develops and maintains a national shared use facility, the Nanofab, with state-ofthe-art, nanoscale measurement and fabrication capabilities in Gaithersburg, MD
- applies a multidisciplinary approach to problem solving that involves partnering with industry, academia, and other government agencies,
- serves as a hub to link the external nanotechnology community to the vast measurement expertise that exists within the NIST Laboratories, and
- helps to educate the next generation of nanotechnologist.

(For information see: http://cnst.nist.gov)



- Research Program Developing measurement capabilities for:
 - Future Electronics
 - Nanofabrication and Nanomanufacturing
 - Energy
- The Nanofab A national, state-of-the-art, shared use facility for the measurement and fabrication of nanostructures both inside and outside of cleanrooms
 - 19,000 sq ft cleanroom (8,000 sq ft class 100)
 - Advanced lithography and microscopy
 - Experienced staff to train users or operate the tools
 - Open to all users



Nanotechnology Characterization Laboratory (of the National Cancer Institute in NIH)



NCI Alliance for Nanotechnology

NCL provides infrastructure support to the Alliance and to nanotech researchers - to overcome obstacles and translate 'nano' into the clinical realm

NCL Objectives

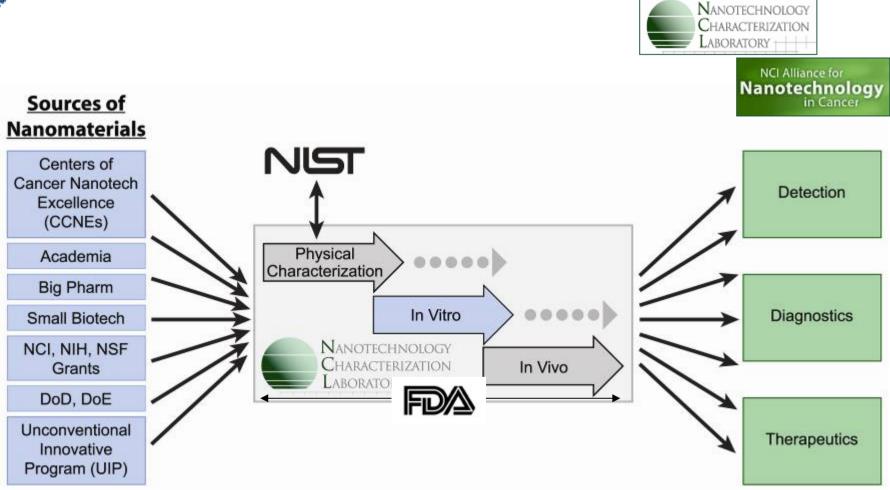
- Characterize nanoparticles using standardized methods
- Conduct structure activity relationships studies
- Facilitate regulatory review of nanotech constructs
- Engage in educational and knowledge sharing efforts

The NCL is a national resource available to investigators from academia, industry and government

ncl@ncifcrf.gov http://ncl.cancer.gov



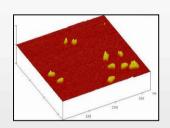
NCL Concept of Operations



NCL is a formal collaboration between NCI, FDA and NIST



NCL Assay Cascade





NCI Alliance for **Nanotechnology** in Cancer

Physicochemical:

- **Size**
- Shape
- **■** Composition
- Molecular weight
- Surface chemistry
- Identity
- **■**Purity
- **■** Stability
- Solubility

In Vitro:

- **■** Pharmacology
- Blood contact properties
- **■** Immune cell function
- **■** Cytotoxicity
- Mechanistic toxicology
- Sterility

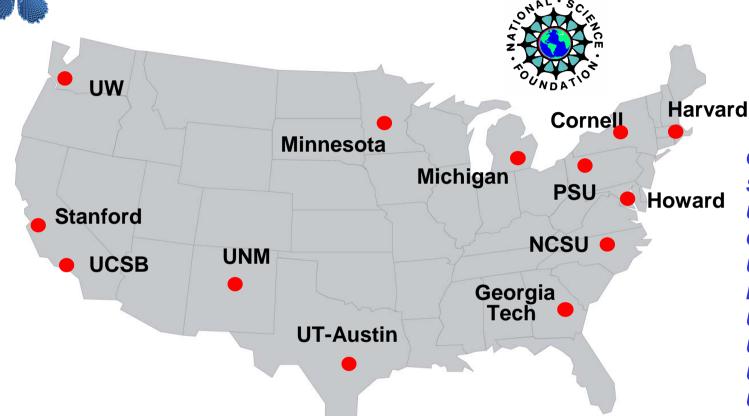


In Vivo:

- **■** ADME
- Safety
- **■** Efficacy

http://ncl.cancer.gov/assay_cascade.asp

National Nanotechnology Infrastructure Network (NNIN)



An integrated national network of user facilities providing researchers open access to resources, instrumentation, and expertise in all domains of nanoscale science, engineering, and technology

Cornell U (Lead)
Stanford U
U Michigan
Georgia Tech
U Washington
Penn State U
UC Santa Barbara
U Minnesota
U New Mexico
U Texas –Austin
Harvard U
Howard U

No. Carolina State U

Nanoscale Science

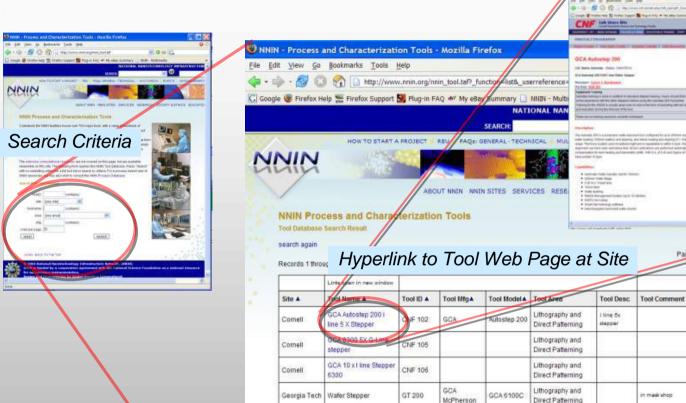
Engineering & Technology

http://www.NNIN.org

13



NNIN Tool Database



Penn State

Stanford

Stanford

Stanford

Stanford

U. C. Santa

Nikon 1505EX Stepper

Nikon Model 1504 5:1

Nikon Body 9 Stepper

Ultratech Model 1000

Ultratech Model 1000

GCA 6300 5X Stepper

1:1 Stepper (#2)

1:1 Stepper

PSU 036

SNF nilkon

nikon-9

ultratech

ultratech2

UCSB 105

SNF

Nikon

Nikon

Nikon

Ultratech

Ultratech

GCARTS

Tools Availability at All Sites

248nm DUV Stepper

Lithography and

Direct Patterning

Lithography and

Direct Patterning

Direct Patterning

Lithography and

Direct Patterning

Lithography and

Direct Patterning

NSR 1505EX

Body 9

1000

1000

NNIN Education and Outreach

Workshops for Journalists, Lawyers, etc Technical Workshops SEI Activities

Professional

Elementary

Children's Magazine School Activities School visits

Equipment &
Process Training
Seminars
Workshops
Open Text Book

Graduate

Middle School Chip Camps
Science Clubs
Curriculum Support
Nanoscience Kits
Travelling Van

REU Workshops Courses Seminars

Undergraduate High School Internships
School Visits
Tours
Mentoring

Internship Programs
Workshops
Workforce Development
Course Support

2 year Colleges

Teachers

RET
Workshops
Curriculum Support
Continuing Education

National – Network wide activities, shared experience Local – Site specific activities with focus on local issues

*DOE's Nanoscale Science Research Centers: Basic Info

- Research facilities for synthesis, processing, fabrication, analysis, characterization, and modeling of nanoscale materials
- Provide specialized equipment, unique tools, and support staff that are difficult for individual institutions to build and maintain
- Operated as user facilities; available to all researchers; access determined by peer review of proposals; cost recovery for proprietary work
- Co-located at DOE National Laboratories with existing major user facilities (synchrotron radiation light sources, neutron scattering facilities, other specialized facilities) to provide characterization and analysis capabilities





The five NSRCs are in operations and serving users



Molecular Foundry (Lawrence Berkeley National Laboratory, CA)



Center for Functional Nanomaterials (Brookhaven National Laboratory, NY)

Center for Nanoscale Materials (Argonne National Laboratory, IL)



Center for Nanophase Materials Sciences (Oak Ridge National Laboratory, TN)

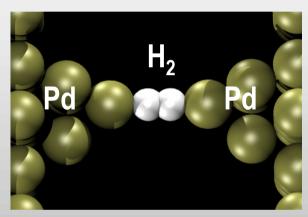


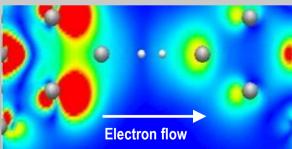
Center for Integrated Nanotechnologies (Sandia & Los Alamos National Labs, NM)

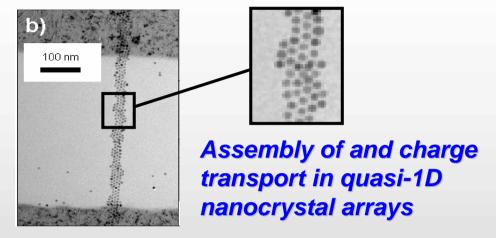


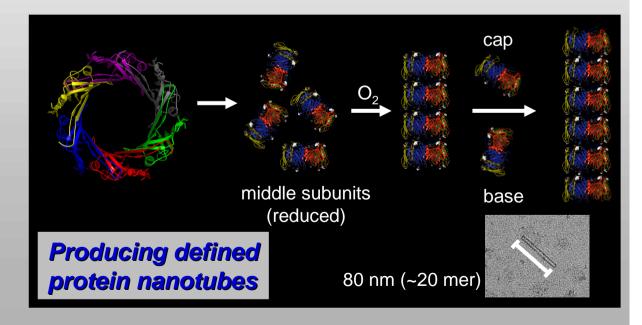
NSRC Instruments, Expertise Support Cutting-edge Research

Calculating resistance across the smallest possible junction





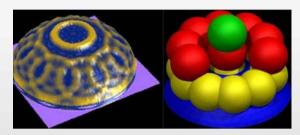




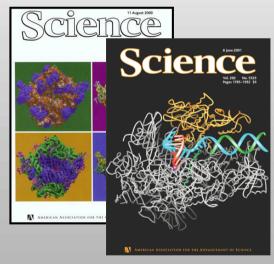


Seeing atoms: National user facilities for probing materials at the atomic scale

X-ray scattering

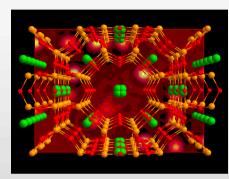


AlNiCo quasicrystal structure

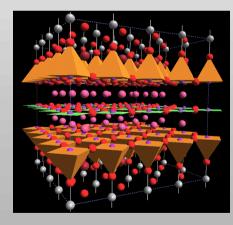


Molecular machines of life

Neutron scattering

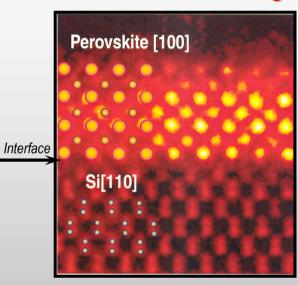


Zeolite catalyst



High Tc superconductor

Electron Scattering



Transmission electron microscope image showing an abrupt interface and low defect density for the ferroelectric SrTiO₃ on Si.

NATIONAL NANOTECHNOLOGY DOE Basic Energy Sciences Scientific User Facilities INITIATIVE 4 Synchrotron Radiation Light Sources
2 additional Light Sources (Under construction)
4 High-Flux Neutron Sources · 3 Flectron Beam Microcharacterization Centers **Electron Microscopy** · 5 Nanoscale Science Research Centers **Center for Materials** 1 Specialized Single-Purpose Facility Research Center for **Advanced Light Intense Pulsed Nanoscale** Source **Neutron Source Materials National Center for** Electron Microscopy Molecular **Foundry**

> Los Alamos **Neutron Science**

> > Center

Center for

Integrated

Nanotechnologies

Stanford **Synchrotron**

Radiation Lab

Linac Coherent Light Source

Combustion **Research Facility**

Synchrotron **Light Source-II Spallation Neutron** Source Center for **Nanophase Materials Sciences Shared Research Equipment Program High-Flux**

Advanced

Photon

Source

Center for

Functional

Nanomaterials

Isotope Reactor

National

Synchrotron Light Source

National

For more information on the NNI



Home Site Map Search Contact Us Privacy

The National Nanotechnology Initiative (NNI) provides a multi-agency framework to ensure U.S. leadership in nanotechnology that will be essential to improved human health, economic well being and national security. The NNI invests in fundamental research to further understand in set financiale phenomena and facilitates technology transfer.



Leading to a Revolution in Technology and Industry

About the NNI

Nanotech Facts

Research

Society & Safety

Funding Opportunities

Nanotechnology Centers

Newsroom

Education Center

Resources

EPA Seeks Input for Safety of Engineered Nanoscale Materials

Jan. 26, 2008—The Environmental Protection Agency (EPA) established a Nanoscale Materials Stewardship Program (NMSP) which is calling upon manufacturers, importers, processors, and users of engineered nanoscale materials to report to EPA key information about the human health and environmental risks and benefits of nanoscale chemical products before July 28, 2008.

"The Nanoscale Materials Stewardship Program will provide a firmer scientific foundation for assessing the hazards, exposures, and risks of chemical nanoscale materials and making appropriate risk management decisions," said Charlie Auer, Director of EPA's Office of Pollution Prevention and Toxics. "It will be important for industry to work with EPA by promptly reporting on their nanoscale material products over the next six months. We are off to a good start having already received our first data submission under the NMSP, and we look forward to more."

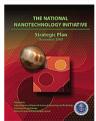
Engineered nanoscale materials range in size from 1-100 nanometers (nm) and may have very different properties than the same materials at a larger scale. EPA will evaluate the information it receives to help ensure the safe manufacture and use of these materials, and the NMSP will complement and support EPA's new and existing chemical programs under the Toxic Substances Control Act (TSCA).

Proposals Sought for Center for Environmental Implications of Nanotechnology



The National Science Foundation and the Environmental Protection Agency have issued a joint solicitation for proposals to create a national Center for Environmental

National Nanotechnology Initiative Strategic Plan Released



The 2007 NNI Strategic Plan describes the vision, goals, and priorities of the NNI. Through the approach described in this new Strategic Plan, the NNI will ensure that the United States derives growing economic benefits and improved quality of life for its citizens, and remains a global leader in nanotechnology R&D in the years to come.

The <u>Nanoscale Science</u>, <u>Engineering</u>, <u>and</u>
<u>Technology</u> (NSET) Subcommittee of the
National Science and Technology Council's

Committee on Technology, with support from the National Nanotechnology Coordination Office, has released a new NNI Strategic Plan as called for in the 21st Century Nanotechnology Research and Development Act (Public Law 108-153) of 2003. This plan updates and replaces the NNI Strategic Plan of December 2004.

In reviewing the basic elements of the existing strategic plan, the NSET Subcommittee found many aspects still relevant and appropriate. However, a number of modifications have been made to reflect progress that has taken place since 2004 and to emphasize and clarify the significance that nanotechnology advances will have for our nation.

As in the earlier strategic plan, this NNI Strategic Plan identifies major subject areas, or program component areas (PCAs), in which investments are needed to ensure success of the initiative. To better understand and manage the NNI investment, the Societal Dimensions PCA defined in the 2004 plan is divided into two PCAs in this updated plan, one titled Environment, Health and Safety and one titled Education and Societal Dimensions. This change aligns with budget reporting practices since 2006.

http://nano.gov